

Contents COMAT 2012

Volume 1

1. L.E. Aciu, P.L. Ogrutan, M. Volmer, ELECTROMAGNETIC SHIELDING PROPERTIES DETERMINATION FOR ADVANCED COMPOSITE MATERIALS.....	1
2. A.M. Olărescu, M. Cionca, MOE AND MOR OF SOLID WOOD PANEL MADE OF TIMBER PROVIDED BY THIN ($D_{max}=160$ mm) QUERCUS PETRAEA SPP. MATT. LIEBL. TREE.....	7
3. A. Deák, M. Cionca, M.C. Timar, EVALUATION OF COATING ADHESION TO MELAMINATED PARTICLEBOARD SURFACES RECOVERED FROM OLD FURNITURE.....	13
4. A.D. Botezatu, M.I. Ursu, O.E. Gradin, M.C. Rusu, SEM STUDY ON FRACTURE BEHAVIOR FOR PA 6 COMPOSITES USED ON AUTOMOTIVE PARTS.....	19
5. C. Casavola, L. Lamberti, C. Pappalettere, DESIGN OPTIMIZATION OF COMPOSITE AEROSPACE STRUCTURES.....	23
6. C. Răcănel, A. Burlacu, DYNAMIC TESTS ON ASPHALT MIXTURES WITH POLYPROPYLENE FIBERS.....	25
7. C.I. Pruncu, A SHORT REVIEW OF RECENT RESEARCH ON THE MECHANICS OF FRACTURE AND FAILURE IN COMPOSITE MATERIALS.....	31
8. C. Florea, H. Iancău, L. Hancu, M. SIMON, RESEARCH REGARDING THE INFLUENCE OF THE REINFORCEMENT DEGREE UPON THE TENSILE STRENGTH OF SOME COMPOSITE MATERIALS.....	37
9. I. Dumitrascu, P.D. Barsanescu, V. Goanta, ELECTRICAL RESISTANCE CHANGE IN CFRP COMPOSITES WITH DIFFERENT FIBRE VOLUME FRACTION UNDER TENSILE LOADING.....	43
10. A. Matei, L. Dumitrescu, I. Cernica, V. SCHIOPU, I. Manciualea, INORGANIC NANOPARTICLES IN POLYMER MATRIX COMPOSITES..	49
11. A. Calenciug, G.N. Radu, DETERMINATION OF MECHANICAL PROPERTIES FOR IMPACT AND BENDING A BUMPER SHOCK ABSORBER MADE OF STEEL COMPARED TO BUMPER SHOCK ABSORBER MADE FROM A NEW COMPOSITE MATERIAL FOR AUTOMOTIVE INDUSTRY - PART 1.....	53
12. A. Olei, G. Benga, I. Stefan, THE INFLUENCE OF THE TRIBOLOGICAL TESTING CONDITIONS ON THE WEAR RATE FOR SOME TITANIUM PLATES PROCESSED BY SPARK PLASMA SINTERING ROUTE.....	57
13. E.V Butila., EXPERT SYSTEM FOR CHOICE OF MATERIALS.....	63
14. C. Atănăsoaei, F. C. Oliveira, EFFECTS OF DIFFERENT REINFORCING PHASE IN CORDIERITE MATRIX COMPOSITES.....	68
15. C. Cerbu, DETERMINATION OF THE STRAINS DEVELOPED IN FURNITURE PARTS MADE OF GLASS FIBRES COMPOSITE MATERIALS.....	73
16. V. Ciofoaia, C. Cerbu, ABOUT THE MACROMECHANICAL CHARACTERISTICS OF COMPOSITE MATERIALS BY DYNAMIC IMPACT TESTS.....	79

17. C. Opran, M.E. Lupeanu, C. Bivolaru, MATHEMATICAL MODELS OF FORCE AND MOMENT IN MACHINING PRODUCTS MADE BY SANDWICH COMPOSITES POLYMERIC MATERIALS.....	83
18. C. Locovei, M. Nicoară, A. Răduță, V.A. Șerban, CONTRIBUTIONS TO COMPUTER-AIDED EVALUATION OF MICROSTRUCTURE FOR PARTICLE REINFORCED COMPOSITES BY MEAN OF IMAGE PROCESSING.....	90
19. M. Růžicka, O. Uher, J. Had, V. Kulíšek, P. Padovec, DESIGN AND APPLICATION OF COMPOSITE MATERIALS IN MECHANICAL STRUCTURES.....	96
20. M.L. Scutaru, C. Cofaru, RESEARCH ON THE IDENTIFICATION OF HEMP COMPOSITES USING TENSILE TESTING.....	102
21. M.L. Scutaru, C. Cofaru, H. Teodorescu-Drăghicescu, RESEARCH ON STUDY HEMP FIBER SUBJECTED TO THREE-POINT BEND TESTS.....	108
22. M.D. Stanciu, I. Curtu, O.M. Terciu, C. Cerbu, S. Nastac, NON-DESTRUCTIVE TESTING TO DETERMINE ACOUSTIC PROPERTIES OF LIGNOCELLULOSES COMPOSITES REINFORCED WITH WEAVE FABRICS OF FLAX FIBERS.....	113
23. M.D. Stanciu, I. Curtu, A. Savin, R. Grimberg, EVALUATION OF GLASS FIBER REINFORCED PLASTIC ELASTIC PROPERTIES USING LAMB WAVES.....	117
24. M. Lupu, F. Isaia, SOLUTION OF THE THERMOELASTIC EQUILIBRIUM PROBLEM FOR CYLINDRICAL TUBES WITH BIG TORSION ANGLE IN THE CASE OF COMPOSITE MATERIAL STRUCTURES.....	123
25. D. Mitrica, V. Soare, I. Constantin, F. Stoiciu, G. Popescu, MICROSTRUCTURAL CHARACTERIZATION OF AlSi7Mg/AlN AND AlSi12Mg/SiC COMPOSITES OBTAINED BY REACTIVE GAS INJECTION METHOD.....	128
26. V. Pomazan, C. L. Petcu, CORRELATION OF THE HUMAN DENTINE HARDNESS AND ELASTIC PROPERTIES	134
27. I.O. Popp, THE BASALT-A MATERIAL USED IN MACHINE TOOLS PARTS MANUFACTURING.....	140
28. F.L. Tămaș, I. Tuns, COMPOSITE MATERIALS AND MODERN TECHNOLOGIES TO WATERPROOFING REHABILITATION.....	144
29. O.M. Terciu, I. Curtu, C. Cerbu, FEM MODELLING OF AN AUTOMOTIVE DOOR TRIM PANEL MADE OF LIGNOCELULOZIC COMPOSITES IN CASE OF A DOOR SLAM SIMULATION.....	148
30. V. Năstăsescu, S. Roateși, COMPARATIVE NUMERICAL STUDY OF FEM AND SPH METHOD FOR BULLET-MULTILAYERED PLATE IMPACT SIMULATION.....	152
31. D. Fiat, M. Lazăr, M. Prună, ECOLOGICAL THERMAL INSULATION COMPOSITE SYSTEMS USED IN CONSTRUCTION.....	158
32. D. Șova, L. Costiuc, D. Cioranu, C. Enășoae, THERMAL CHARACTERISTICS OF WOOD-BASED MIXTURES BIOMASS	165
33. D.D. Nicoara, ON THE NUMERICAL ANALYSIS OF COMPOSITE MATERIAL.....	171
34. E. Kormaníková, DESIGN OPTIMIZATION PROCESS WITH APPLICATION TO THE COMPOSITE STRUCTURAL ELEMENT.....	177
35. E.F. Beznea, C.A. Vasilache, I. Chirica, FEM BUCKLING BEHAVIOR STUDIES ON COMPOSITE PLATES WITH INITIAL IMPERFECTIONS....	183

36. F. Popescu, I.V. Ion, THE STUDY OF A SEPARATING AND REATTACHING FLOW TOPOLOGY.....	189
37. G.N. Basescu, G.L. Pintilei, M. Benchea, A.C. Barbanta, I.V. Crismaru, C. Munteanu, COATING PROPERTIES OBTAINED BY THERMAL DEPOSITION USED IN CAMS/CAMS FOLLOWERS APPLICATIONS.....	193
38. G. Amza, C. Florică, G.D. Tașcă, I. Ciobanu, CONTRIBUTIONS TO NONCONTACT ULTRASONIC EXAMINATION OF COMPOSITE MATERIALS USED IN CIVIL AND INDUSTRIAL CONSTRUCTION.....	200
39. G. Amza, C. Florică, G.D. Tașcă, Z. Apostolescu, THEORETICAL AND EXPERIMENTAL CONTRIBUTIONS REGARDING INFRARED THERMOGRAPHY EXAMINATION OF COMPOSITE MATERIALS USED IN CIVIL AND INDUSTRIAL CONSTRUCTION.....	205
40. I. Chirica, E.F. Beznea, STRENGTH ANALYSIS OF THE SHIP DECK DELAMINATED PLATES AT EXPLOSIONS.....	211
41. I. Constantinescu, E. Vasilescu, R.I. Novac, COMPOSITE COATINGS IN ZINC MATRIX WITH SiO_2 IN DISPERSED PHASE OBTAINED BY ELECTRODEPOSITION.....	217
42. I. Dumitrascu, P.D. Barsanescu, V. Goanta, ELECTRICAL RESISTANCE CHANGE IN CFRP COMPOSITES WITH DIFERENT FIBRE VOLUME FRACTION UNDER TENSILE LOADING	222
43. I. Constantinescu, F. Oprea, O. Mitoseriu, A COMPARATIVE STUDY OF THE PROPERTIES OF ZINC- SiO_2 AND ZINC- Al_2O_3 COMPOSITE LAYERS.....	228
44. I. Sprințu, ANALYSIS OF COMPOSITE RECTANGULAR PLATES BASED ON THE CLASSICAL LAMINATED PLATE THEORY.....	233
45. K. Kotrasová, DYNAMICAL ANALYSIS OF COMPOSITE RESERVOIR.....	239
46. L.G. Pintilei, V. Manoliu, G. Ionescu, G.N. Basescu, S.C. Iacob Strugariu, C. Munteanu, BEHAVIOR TO HIGH SPEEDS HEATING-COOLING OF CERAMIC MULTILAYER MULTIFUNCTIONAL STRUCTURES BASED ON THE ZIRCONIE PARTIAL STABILIZED WITH YTTRIA.....	245
47. M. Stan, P. Stan, SPECTRAL RESPONSE FOR THE DUFFING OSCILLATOR WITH NON-LINEAR ELASTIC CHARACTERISTIC.....	252
48. A. Patrascu, C. Opran, STUDY ON DETERMINING THE MOMENTS REGRESSION RELATIONS AT DRILLING IN MINERAL COMPOSITE MATERIALS WITH 2% CONCENTRATION OF GLASS FIBER.....	256
49. P. Stan, M. Stan, SPECTRAL RESPONSE FOR N RANDOM EXCITATIONS OF A NON-LINEAR OSCILLATOR WITH NON-LINEAR DAMPING CHARACTERISTIC IN THE FLUID MEDIUM.....	262
50. S. Nastac, C. Debeleac, A. Leopa, I. Curtu, M.D. Stanciu, ELASTOMERIC BASED COMPOSITES INTENDED FOR IMPACT PROTECTIVE DEVICES.....	267
51. S. Nastac, PARTICULAR BEHAVIOUR OF CERTAIN COMPOSITES RELATED TO BASIC DAMAGE DETECTION TECHNIQUES.....	272
52. V. Geamăn, I. Popa, A.M. Pop, MULTIFUNCTIONAL ADVANCED MATERIALS – THE KEY FOR NEW TECHNOLOGY AREAS. A SHORT OVERWIEV.....	278
53. V. Geamăn, RHEOCASTING PROCESS APPLIED TO ATSi_5Cu_1 ALLOY...	282

54.	Z. Apostolescu, G. Amza, M. Dragomir Groza, S.L. Paise, CONTRIBUTIONS TO ULTRASONIC WELDING OF INTELLIGENT COMPOSITE MATERIALS USED IN VEHICLE MANUFACTURING.....	285
55.	Z. Apostolescu, G. Amza, S.L. Pais, M. Dragomir Groza, CONTRIBUTIONS ON THE INFLUENCE OF MECHANICAL PARAMETERS TO THE QUALITY OF WELDED JOINTS OF SMART COMPOSITES IN ULTRASONIC FIELD... ..	291
56.	D.M. Constantinescu, Șt. Sorohan, A. Sandu, M. Sandu, D.A. Apostol, A STUDY ON THE PARAMETERS THAT INFLUENCE THE PERFORMANCE OF SANDWICH PANELS WITH CHIRAL TOPOLOGY CORES.....	297
57.	G.N. Comșa, CONCEPTION OF AN EXPERT SYSTEM MODEL OF FURNITURE FINISHING TECHNOLOGIES.....	303
58.	K. Jármai, STRUCTURAL OPTIMIZATION FOR COST.....	308
59.	M. Barbuta, M. Harja, NEW TYPES OF COMPOSITE.....	314
60.	R. Purcarea, V.Gheorghe, M.V. Munteanu ENDURANCE TESTS ON SPECIMENS FROM COMPOZITE MATERIALS SANDWICH TYPE.....	320
61.	C. Cerbu, ASPECTS CONCERNING TO THE IMPACT CHARPY TESTING IN CASE OF COMPOSITES MATERIALS FILLED WITH WOOD FLOUR.....	325
62.	M.E. Lupeanu, C. Opran, C. Neagu, A. EW Rennie, FUNCTIONAL ANALYSIS FOR THE DEVELOPMENT OF BIO-MEDICAL PRODUCTS...	330
63.	A. Calieniug, G.N. Radu, DETERMINATION OF MECHANICAL PROPERTIES FOR IMPACT AND BENDING A BUMPER SHOCK ABSORBER MADE OF STEEL COMPARED TO BUMPER SHOCK ABSORBER MADE FROM A NEW COMPOSITE MATERIAL FOR AUTOMOTIVE INDUSTRY - PART 2.....	337



STRUCTURAL OPTIMIZATION FOR COST

K. Jármai¹

¹ University of Miskolc, Miskolc, HUNGARY, altjar@uni-miskolc.hu

Abstract: The paper deals with the cost of composite materials. It shows, that there are several benefits using composite materials, but to select the proper composite one should know its properties better. The factors governing fibre selection include; density, cost, strength and modulus. An example shows the cost calculation of a composite beam with prepreg.

Keywords: composite materials, cost calculation, fibre selection

1. INTRODUCTION

Composites offer engineers a new freedom to optimize structural design and performance. Composites have several advantages over conventional metallic structures. The most significant of these are:

- Low density leads to high specific strength and modulus. Very strong and stiff structures can be designed, with substantial weight savings.
- Fibre can be orientated with the direction of principle stresses, increasing structural efficiency.
- Exceptional environmental and corrosion resistance.
- Improved vibration and damping properties.
- The ability to manufacture complex shapes and one offs from low cost tooling.
- Very low and controllable thermal expansion.
- Excellent fatigue resistance, carbon fibre composites can be designed to be essentially fatigue free.
- Potential for energy absorbing safety structures.
- Damaged structures can be easily repaired.

The costs of the composites are very different. Some of them are relatively cheap, some are expensive. The aim of this study is to show some information about cost calculation, to help designers to choose the proper material. For comparison the main metals, the wood and the concrete is compared to composites through density, tensile modulus and tensile strength [1]. Figure 1-3 show these comparisons.

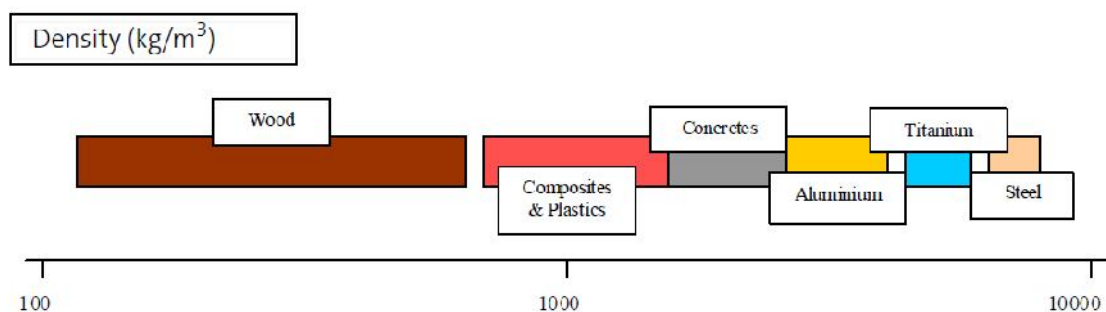


Figure 1. Comparison of the density of different materials

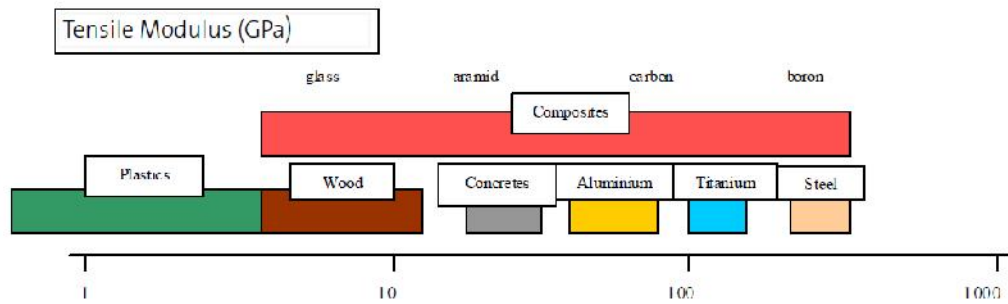


Figure 2. Comparison of the tensile modulus of different materials

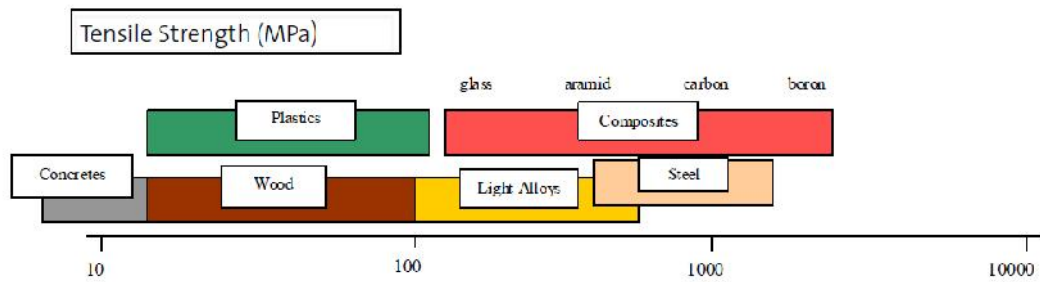


Figure 3. Comparison of the tensile strength of different materials

2. KEY FIBRE SELECTION CRITERIA

Within the composite materials there is still a great difference between the properties. Factors governing fibre selection include; density, cost, strength and modulus. Figures 4 to 7 give comparisons of these factors for a range of fibre types.

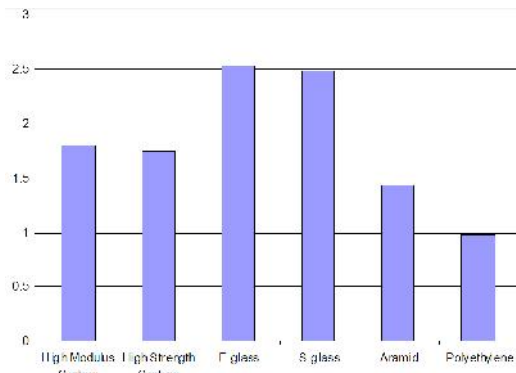


Figure 4. Relative Properties – Density

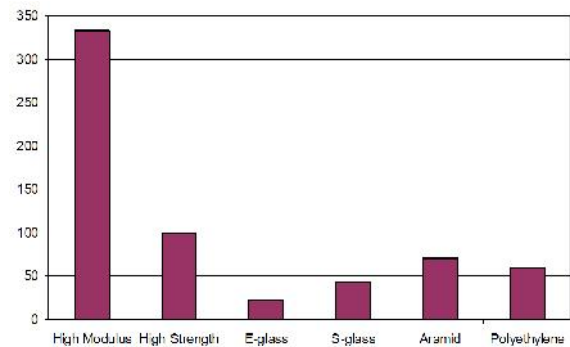


Figure 5. Relative Properties – Cost Ratio

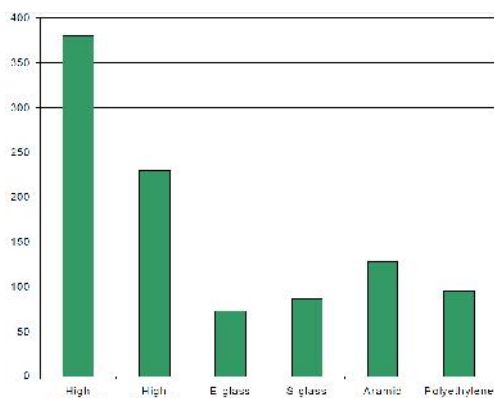


Figure 6. Relative Properties – Modulus GPa

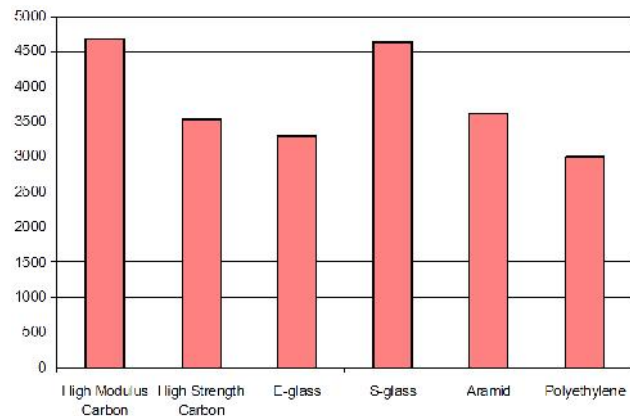


Figure 7. Relative Properties - Tensile Strength MPa

3. THE COST FUNCTION

Calculate different structures the cost function may include the cost of material, assembly, the different fabrication costs such as welding, surface preparation, painting and cutting, edge grinding, forming the geometry and are formulated according to the fabrication sequence. Not too much research has been done in this field, but we have to refer to the work of Klansek & Kravanja [3,4], Jalkanen [5], Timár et al. [6], Farkas & Jármai [7,8,9]. For composites the calculation is very different and there are some good information available on the internet [10, 11].

3.1. The cost of material

$$K_M = k_M \rho V, \quad (1)$$

for steel the specific material cost can be $k_M = 1.0$ \$/kg, for glass fibre 20-30 \$/m² depending on the thickness. where K_M [kg] is the fabrication cost, k_M [\$/kg] is the corresponding material cost factor, V [mm³] is the volume of the structure, ρ is the density of the material. For steel it is 7.85x10⁻⁶ kg/mm³. If several different materials are used, then it is possible to use different material cost factors simultaneously in Eq. (1).

3.2. The fabrication cost in general

$$K_f = k_f \sum_i T_i, \quad (2)$$

where K_f [\$] is the fabrication cost, k_f [\$/min] is the corresponding fabrication cost factor, T_i [min] are production times. It is assumed that the value of k_f is constant for a given manufacturer. If not, it is possible to apply different fabrication cost factors simultaneously in Eq. (2).

4. GENERIC ATL PROCESS LOOKS AS FOLLOWS

- Tooling Manufacture
- Clean Mould
- ¹ Tooling Preparation
- Pre-preg
- ² ATL pre-preg tape n layers
- Consumables
- ³ Thermo form
- ⁴ Curing
- ⁵ Remove part & debug
- ⁶ Part Finishing
- ⁷ Non Destructive Testing
- ⁸ Part Transfer

Table 3 Mechanical properties and feedstock cost for typical prepreg laminates (fibre fraction-0.6, QI lay-up) [2]

Fibre	Resin	Young's modulus (GPa)	Shear modulus (GPa)	Design tensile strength (MPa)	Laminate density (kg/m ³)	Feed-stock costb (€/kg)
E-glass	Epoxy	22	8.7	110	1980	65
Aramid	Epoxy	30	11	112	1382	95
HS carbon	Epoxy	55	22	220	1560	100
IM carbon	Epoxy	68	27	280	1560	220

4.1. Fixed capital investments and manufacturing cost estimation for higher capacities of carbon fibre plant

Fixed capital investment estimation for similar kind of plant:

$$C_{FC,b} = C_{FC,a} (r_{mb}/r_{ma})^{0.7} \quad (3)$$

where,

r_{ma} = monthly production rate of plant a

r_{mb} = monthly production rate of plant b

$C_{FC,a}$ = Fixed capital investment of plant a

$C_{FC,b}$ = Fixed capital investment of plant b

This method is an adaptation of the six-tenth-factor rule, which applies for use in estimation of equipment cost. A similar rule is applied to fixed capital investment except that the absolute value of the power term is governed by following conditions:

- For the average chemical process, the power term will be 0.7 as shown in equation
- For very small installation or for processes employing extreme conditions of temperature or pressure, the value of power term will be from 0.3 to 0.5
- For plant achieving higher capacities through the employment of a high proportion of multiple units rather than large-sized equipment, the term will be 0.8

4.2. Manufacturing cost estimation for carbon fiber plant:

$$A_p = 0.09 * C_{FC} + 16200 * C_L * N + A_U \quad (4)$$

where

A_p = Annual processing cost

C_{FC} = Fixed capital investment

C_L = Labour charges (€/hr)

N = Number of persons working per shift

A_U = Annual utility and raw material cost

$$\begin{aligned} A_p &= 0.09 * 125000000 + 16200 * (300/24) * 25 + 150000 * 300 \\ &= 3100 \text{ / year for 20000 kg of carbon fibres} \\ &= 3100 \text{ €/kg of carbon fibre} \end{aligned}$$

The annual processing cost for A_{p2} for a similar plant of a different size designed for annual production rate R_2 can be approximately calculated by

$$A_{p2} = 0.09 * C_{FC1} (R_2/R_1)^{0.7} + 16200 * C_L * N_1 (R_2/R_1)^{0.25} + A_{u1} (R_2/R_1) \quad (5)$$

A similar approach for estimating manufacturing cost with a power factor of 0.8 for utilities is as

$$A_{p2} = 0.09 * C_{FC1} (R_2/R_1)^{0.7} + 16200 * C_L * N_1 (R_2/R_1)^{0.25} + A_{u1} (R_2/R_1)^{0.8} \quad (6)$$

Table 2. Estimated fixed capital investment (excluding land, building and fire hydrant system)

Plant capacity of carbon fibres tons/year	Estimated fixed capital investment (Crores)	Estimated manufacturing cost of carbon fibres €/kg Eq.5	Estimated manufacturing cost of carbon fibres €/kg Eq.6
20	12.5	45.8	45.8
100	35	39.1	30.3
300	65	37.4	23.6
600	100	36.5	20.4
1000	150	35.9	18.5

5. SIMPLE EXAMPLE FOR COST CALCULATION AT FRP

We have made a calculation of the composite beam cost considering the recurring and non-recurring cost system. Part Dimensions and Features (Figure 8)

Part Length	10 m	Flange Width	0.13 m
Web Height	0.9 m	Flange Thickness	0.02 m

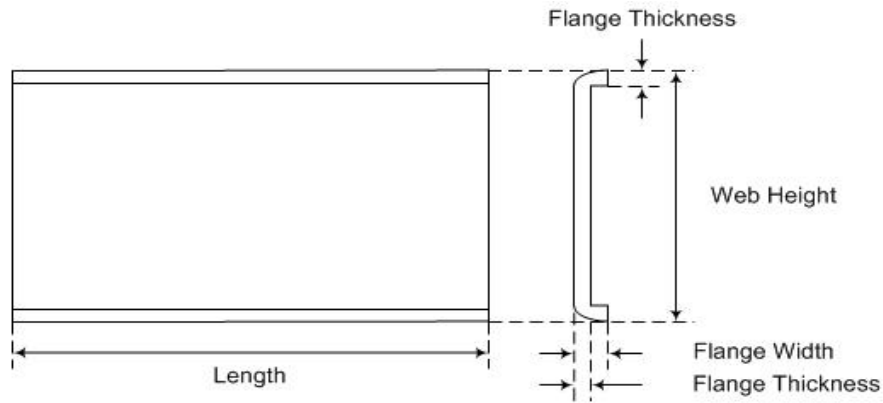


Figure 8. The composite beam cross section

5.1. Recurring Cost Summary Sheet

Labour Recurring Costs [2]

Labour	Manufacturing Hours	Charge Rate €/hour	Cost €
Clean Mould Tooling	1.99	64.3	127.9
ATL Part	5.26	138.5	728.5
Forming	5.68	80.4	456.7
Autoclave Cure Part	0.50	80.4	40.2
Debag Part	2.71	80.4	217.9
"finishing" (machining)	3.72	138.5	515.2
Non Destructive Inspection	5.30	80.4	426.1
Part Transfer	n/a	n/a	0.00
		Sub total	2512.5
Machine Rib Posts and de-burr on bench	3.00	86.6	259.9
Assembly metal Rib Posts to Part	4.00	77.9	311.7
Total Labour Recurring Costs	32.16		3084.0
Total Material Recurring Costs			9490.3
Total Recurring Costs			12574.3 per Part

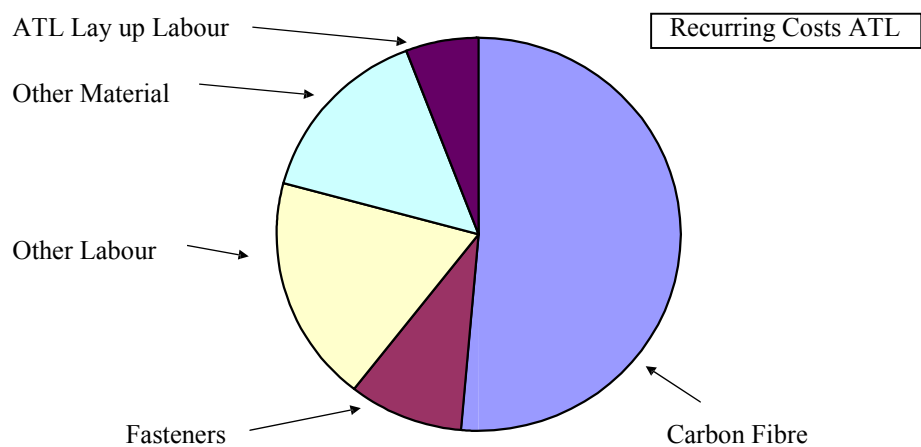


Figure 9. Distribution of the recurring costs at CFRP beam

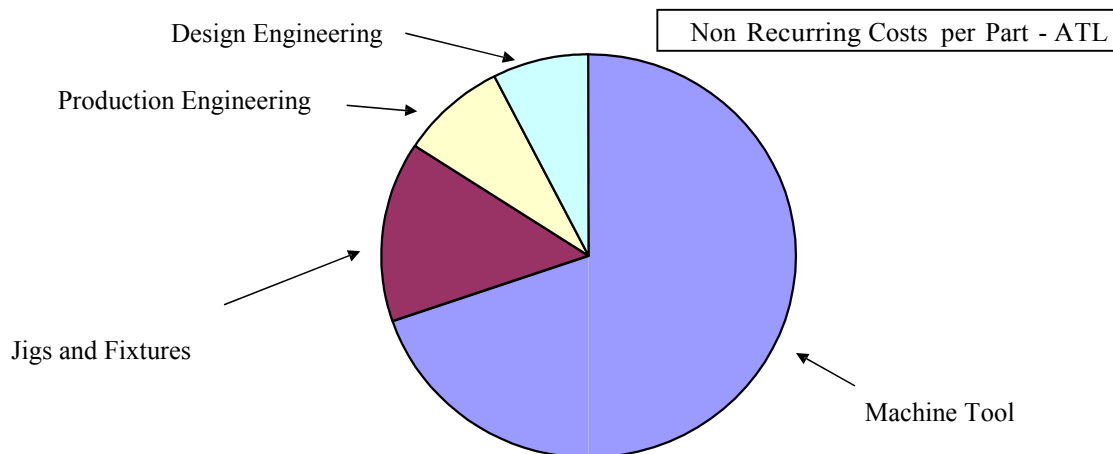


Figure 10. Distribution of the non-recurring costs at CFRP beam

6. CONCLUSION

The composites offer engineers new opportunities to optimize structural design and performance. Composites have several advantages over conventional metallic structures. The paper deals with the cost of composite materials. It shows, that to select the proper composite one should know its properties better. The factors governing fibre selection like density, cost, strength and modulus have an important role. An example shows the cost calculation of a composite beam.

ACKNOWLEDGEMENTS

The research was supported by the Hungarian Scientific Research Fund OTKA T 75678 and by the TÁMOP 4.2.1.B-10/2/KONV-2010-0001 entitled "Increasing the quality of higher education through the development of research - development and innovation program at the University of Miskolc supported by the European Union, co-financed by the European Social Fund."

REFERENCES

- [1] http://www.advanced-composites.co.uk/data_catalogue/catalogue%20files/sm/SM1010-INTRO%20TO%20ADV%20COMPS-Rev06.pdf
- [2] http://www.acoste.org.uk/uploads/EMC_seminars/COST-STUDIO-example.pdf
- [3] Klansek, U. & Kravanja, S. (2006a) Cost estimation, optimization and competitiveness of different composite floor systems – Part 1. Self manufacturing cost estimation of composite and steel structures, *Journal of Constructional Steel Research*, **62** No. 5, pp. 434-448.
- [4] Klansek, U. & Kravanja, S. (2006b) Cost estimation, optimization and competitiveness of different composite floor systems – Part 2. Optimization based competitiveness between the composite I beams, channel-section and hollow-section, *Journal of Constructional Steel Research*, **62** No. 5, pp. 449-462.
- [5] Jalkanen, J. (2007) *Tubular truss optimization using heuristic algorithms*, PhD. Thesis, Tampere University of Technology, Finland. 104 p.
- [6] Tímár, I., Horváth, P. & Borbély, T. (2003) Optimierung von profilierten Sandwichbalken, *Stahlbau*, **72** No. 2. 109-113.
- [7] Farkas, J. & Jármai, K. (1997) *Analysis and Optimum Design of Metal Structures*. Balkema Publishers, Rotterdam, Brookfield,
- [8] Farkas J. & Jármai K. (2003) *Economic design of metal structures*, Millpress Science Publisher, Rotterdam, 340 p. ISBN 90 77017 99 2
- [9] Farkas, J., Jármai, K.: Design and optimization of metal structures, Horwood Publishers, Chichester, UK, 2008. 328 p. ISBN: 978-1-904275-29-9
- [10] R. G. Boeman, N. L. Johnson, "Development of a Cost Competitive, Composite Intensive, Body-in-White," Proceedings of 2002 Future Car Congress, Arlington, Virginia, June 3-5, 2002
- [11] Michael G. Bader, Selection of composite materials and manufacturing routes for cost effective performance, *Composites: Part A* 33 (2002) 913–934.